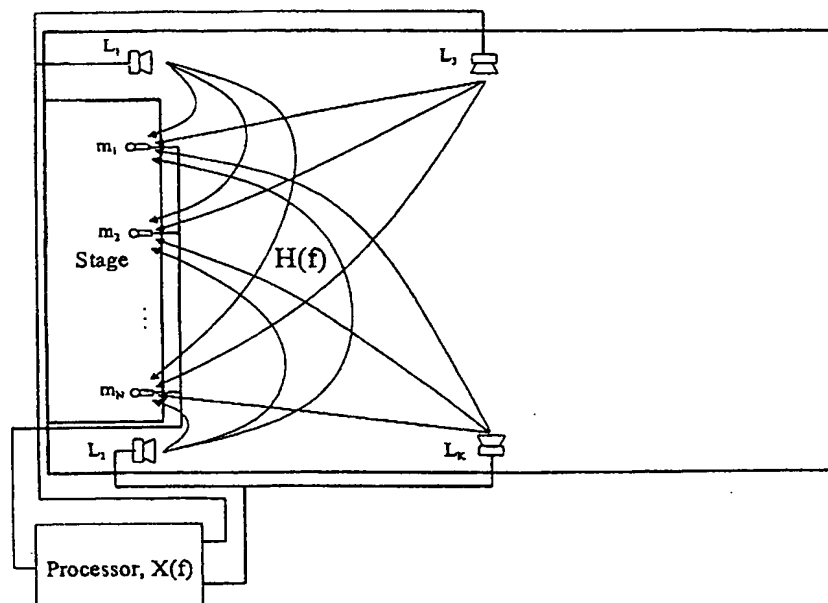




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>G10K 15/08</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 99/54867</b> <b>(43) International Publication Date:</b> 28 October 1999 (28.10.99)
<b>(21) International Application Number:</b> PCT/NZ99/00049 <b>(22) International Filing Date:</b> 23 April 1999 (23.04.99) <b>(30) Priority Data:</b> 330268                      23 April 1998 (23.04.98)                      NZ <b>(71) Applicant (for all designated States except US):</b> INDUSTRIAL RESEARCH LIMITED [NZ/NZ]; Gracefield Road, Lower Hutt 6009 (NZ). <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> POLETTI, Mark [NZ/NZ]; Flat 20, 20 Invercargill Drive, Kelson, Wellington (NZ). <b>(74) Agents:</b> WEST-WALKER, Gregory, James et al.; Russell McVeagh West-Walker, Level 18, Mobil on the Park, 157 Lambton Quay, Wellington (NZ).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

**(54) Title:** AN IN-LINE EARLY REFLECTION ENHANCEMENT SYSTEM FOR ENHANCING ACOUSTICS

**(57) Abstract**

An in-line early enhancement generation system comprises one or more microphones positioned close to one or more sound sources so as to detect predominantly direct sound, an early reflection generation stage which generates a number of delayed reproductions of the microphone signals and which has unitary power gain whereby the stability of the system is independent of the delay times and amplitudes, and a number of loudspeakers placed to broadcast said early reflected energy into the room.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

**AN IN-LINE EARLY REFLECTION ENHANCEMENT  
SYSTEM FOR ENHANCING ACOUSTICS**

**5 TECHNICAL FIELD**

The invention comprises an in-line early reflection enhancement system and method for enhancing the acoustics of a room or auditorium.

**10 BACKGROUND**

The acoustics of a room has a significant impact on an audience's perception of the quality of a live performance. There are a number of properties of rooms that have been identified as being correlated to subjective impressions of quality. The earliest  
15 measured parameter was the reverberation time. This is a global property of the room which has a similar value at all locations. It is governed by the room volume and the absorption of the room surfaces, and the quality of reverberation is also governed by the room shape. Rooms with a long reverberation time can provide a  
20 sense of envelopment which produces an increased enjoyment of performances such as opera or classical music. However, the same acoustics can reduce the intelligibility of the spoken word, and therefore be unsuitable for speech.

Other parameters have been determined which relate to the properties of the early part of the response, such as the clarity. More recent auditoria have been designed  
25 with reflectors specifically placed to enhance the early part of the room response to sounds emanating from the stage.

To achieve maximum enjoyment of a variety of performances, the acoustics of a room must be matched to the intended performance. Many rooms have for this  
30 reason been made acoustically adjustable. For example adjustable absorbers such as moveable curtains or rotatable panels have been used to control reverberation time. Extra acoustic spaces have been constructed which can be coupled to the main area when required to provide more reverberance.

Electroacoustic systems have been used for many years to enhance the acoustics of rooms. The simplest system is the public address or sound reinforcement system, in which the sound produced by performers on stage is detected by close microphones and the sound amplified and broadcast from one or more sets of loudspeakers. The  
5 goal of such systems is typically to project the direct, unreverberated, sound to the audience to eliminate the effects of the room and improve clarity.

More recently, more complex forms of sound system have been developed which aim to provide adjustable room acoustics. The basic sound reinforcement system has  
10 been further developed by introducing sound processing elements such as delays, which allow the creation of additional sound reflections - see W. Anhert, "Complex simulation of acoustic fields by the delta stereophony system (DDS)," *J. Audio Eng. Soc.*, vol. 35, no. 9, pp 643-652, September 1987, and US patent 5,142,586. The delta stereophony system described by Anhert provides sound reflections that are  
15 arranged to arrive later than the direct sound, in order to maintain correct localisation. For a given receiver location, the appropriate delays can be chosen to avoid preceding the direct sound, but the delays must be changed for different receiver positions. The ACS system described in US patent 5,142,586 claims to  
20 provide reflections at the appropriate times for all receiver positions, by the creation of wavefronts. The delays are chosen using Huygens principle, and their quantification mathematically by integral equations is described by A. J. Berknout, D. de Vries, and P. Vogel, "Acoustic control by wave field synthesis," *J. Acoust. Soc. Am.*, vol. 93, no. 5, pp 2764-2778, May 1993. The wavefronts are generated using  
25 loudspeaker arrays. These electroacoustic systems offer a more controllable early reflection response than can be achieved using passive reflectors.

Reverberators have also been introduced to provide a larger reverberation time for sources on stage - see for example US patent 5,109,419. Larger numbers of  
speakers have also been employed to provide enhanced reflections and  
30 reverberation, such as to under balcony areas. The microphones have also been positioned further from the performers so as to be less obtrusive, while still aiming to detect the direct sound.

The systems discussed above avoid feedback from the loudspeakers to the  
35 microphones, since such feedback can lead to colouration and instability if the loop

gain is too high. Because of this fact, they may be generically termed in-line, or non-regenerative, systems. Such systems can provide large increases in reverberation for sound sources that are close to the microphones (ie on stage), but they have a small effect for sound sources at other positions in the room.

5

A second type of enhancement system is the non-in-line, or regenerative, system, which seeks to utilise the feedback between loudspeakers and microphones to achieve a global enhancement of reverberation that occurs for any sound source position - see A. Krokstad, "Electroacoustic means of controlling auditorium acoustics," *Applied Acoustics*, vol. 24, pp 275-288, 1998 and F. Kawakami and Y. Shimizu, "Active field control in auditoria," *Applied Acoustics*, vol. 31, pp 47-75, 1990. Since the natural, unassisted reverberation time is largely the same for all source positions, the regenerative systems can provide a more natural enhanced reverberation. Non-in-line systems typically use a large number of independent microphone, amplifier, loudspeaker channels, each with a low loop gain. Each channel provides a small enhancement of reverberation at all frequencies, with low risk of colouration, and the combined effect of all the channels is a significant increase in reverberation and loudness. The microphones are positioned in the reverberant field from all sound sources in the room to ensure that the system produces a similar enhancement for all sources. Non-in-line systems, however, have typically required from 60 to 120 channels, and have therefore been expensive. Furthermore, since the microphones are remote from all sources, they are less suited to providing significant early reflections than in-line systems.

More recently, a non-in-line system has been developed which uses a multichannel reverberator between the microphones and loudspeakers to provide an increase in reverberation time without requiring an increase in loop gain - see US patent 5,862,233. It has been shown that the system can both reduce the apparent room absorption (by increasing the loop gain) and increase the apparent room volume (by increasing the reverberation time of the reverberator) - see M. A. Poletti, "The performance of a new assisted reverberation system," *Acta Acustica*, 2 December 1994, pp 511-524. In general, a hybrid room enhancement system may be constructed in which some of the microphones of a non-in-line system containing a reverberator are moved close to the source. In this case the system demonstrates properties of both in-line and non-in-line systems - see M. A. Poletti, "The analysis

of a general assisted reverberation system," accepted for publication in *Acta Acustica* vol. 84, pp 766-775, 1998.

5 When used solely for early reflection enhancement, an in-line system provides a finite number of delayed outputs to simulate early reflections. However, if operated at moderate to high gains, the system runs the risk of instability. This is particularly likely if new delays/reflections are added which will increase the loop gain at some frequencies.

10 In any sound system, it is important that the direct acoustic sound from the stage arrives at every member of the audience before (or at the same time as) any electroacoustic signal. This is because the perception of localisation is governed by the first signal to arrive at the ears (provided later signals are not overly large). Hence, care must be taken in both in-line and non-in-line systems to ensure that  
15 the electroacoustic signals are suitably delayed. In a non-in-line system this can be achieved by keeping the microphones a suitable distance from the stage. Delays can be used in in-line systems and non-in-line systems to avoid preceding the direct sound. Care must therefore be taken in any non-in-line system where microphones are moved close to the stage.

20

#### **SUMMARY OF INVENTION**

In broad terms in one aspect the invention comprises an in-line early reflection generation system comprising:

25 one or more microphones positioned close to one or more sound sources so as to detect predominantly direct sound;

an early reflection generation stage which generates a number of delayed reproductions of the microphone signals and which has unitary power gain whereby the stability of the system is independent of the delay times and amplitudes;

30 a number of loudspeakers placed to broadcast the early reflected energy into the room.

The in-line early reflection generation stage may include a number of delay lines which are preceded or followed by cross coupling matrices.

5 The system and method of the invention do not attempt to optimise the delay time for individual receiver positions as in delta stereophony, nor create wavefronts as in the ACS system. Instead, early reflections are generated in such a way that the stability of the system is maximised. This is achieved by ensuring that the reflection generation circuit has a unitary property.

10 In the system and method of the invention unitary circuit principles are applied to an in-line reflection generation system. In any early reflection system there is a finite level feedback of sound from the loudspeakers to the microphones via the reverberant field in the room. The generation of multiple reflections via multiple delays and amplitude weightings in prior art early reflection systems increases the  
15 risk of instability by creating variations in the loop gain both below and above the levels that would have existed without the system.

However, if the system has a transfer function matrix which is unitary, then the power gain of the system is one at all frequencies, and the stability of the sound  
20 system is not compromised by the insertion of the early reflection system.

Suppose the matrix of transfer functions through the early reflection system is  $X(f)$ . The unitary property states that

$$25 \quad X^H X = I \quad 1$$

where the H superscript denotes the conjugate transpose of the matrix. Consider a single frequency  $f_0$  applied to each input of  $X$ , with amplitude  $A_n$  and phase  $\phi_n$ . The input signal  $s_{in}(t)$  may be written

$$30 \quad s_{in}(t) = e^{j2\pi f_0 t} u \quad 2$$

where  $u$  is the complex amplitude vector

$$u = [A_1 e^{j\phi_1}, A_2 e^{j\phi_2}, \dots, A_N e^{j\phi_N}]^T$$

3

The total output power is

$$y^H(t)y(t) = u^H X^H(f_0)X(f_0)u = u^H u$$

4

since  $X$  is unitary. Hence, the power gain of a unitary system is one at all frequencies, and does not affect stability when inserted into a multichannel system which contains feedback.

10

US patent number 5,729,613 describes a multi-channel reverberator which has this unitary property. This device provides multiple channels of reverberation while maintaining a constant power gain with frequency, and is designed for application in a non-in-line system for reverberation time enhancement, as described in US patent 5,862,233. The device contains multiple channels of internal feedback which creates an infinitely long decaying response, and a rapidly increasing density of echoes which are perceived as reverberation.

In this invention early reflection systems are disclosed which also have a unitary property. They are distinguished from the unitary reverberator in that they do not contain internal feedback, and do not produce an infinite decaying response. Instead they produce a finite response consisting of a relatively low number of discrete echoes. The response is therefore not perceived as reverberation.

It is important to note that in the unitary early reflection system of the invention there is no recursion in the reflection system, ie there is not feedback of the outputs of delay lines to the inputs of delay lines. In contrast to a reverberator the response of the reflection system is therefore finite - the response to an impulse is a short burst of echoes then silence. Also, the density of the echoes will never reach that of a reverberator. Typically system of the invention will have a response time of only 80ms or so, and the echo density never reaches that of a reverberator.



## BRIEF DESCRIPTION OF THE FIGURES

The invention is further described with reference to the accompanying figures, by way of example and without intending to be limiting, in which:

5

Figure 1 shows the layout of an early reflection system of the invention,

Figure 2 shows a unitary n-channel delay line system as the early reflection generation stage,

10

Figure 3 shows a unitary cross-coupled n-channel delay system including an orthonormal matrix before the delay lines as the early reflection generation stage,

15

Figure 4 shows a unitary dual cross-coupled n-channel delay system using orthonormal matrices both before and after the delay lines as the early reflection generation stage,

20

Figure 5 shows a two stage unitary dual cross-coupled n-channel delay system with cascaded orthonormal matrices and delay lines between each two matrices as the early reflection generation stage, and

25

Figure 6 shows a non-in-line assisted reverberation system for controlling the global reverberation time of a room or auditorium with which the in-line early reflection system of the invention may be combined.

## DETAILED DESCRIPTION OF PREFERRED FORMS

Figure 1 shows the layout of an early reflection system of the invention. A number of microphones  $m_1$  to  $m_N$  are positioned close to the sources on stage. The microphone signals are fed to a processor which generates a number of scaled and delayed replicas of the N microphone signals, and the processor outputs are fed to amplifiers and loudspeakers  $L_1$  to  $L_K$  placed in the room. The transfer function matrix of the processor is denoted  $X(f)$ .

The microphones are typically directional, that is, they are sensitive to sound sources positioned on axis, and tend to suppress sound sources (and reflections and reverberation) which are positioned off-axis. This maximises the direct sound pickup and reduces the risk of feedback from the loudspeakers. However, a finite level of feedback may still exist, and if the loop gain of the system is too high, the system will become unstable. The transfer function matrix from the loudspeakers to the microphones is  $H(f)$ , and the loop transfer function matrix is thus  $H(f)X(f)$ . If the locus of any eigenfunction of  $H(f)X(f)$  encircles the point  $(1+j0)$ , the system will be unstable.

The stability of the system can be maintained by keeping the loop gain low, for example by keeping the amplifier or microphone preamplifier gains low. However, for a given setting of amplifier gains, the stability of the system is dependent on the particular delay times and delay levels in the processor. Hence, the system stability cannot be guaranteed once the amplifier gains are set. However, if  $X(f)$  has a unitary property, its power gain is unity at all frequencies. The stability is then independent of the delay times and levels.

Unitary early reflection systems of the invention may be constructed using non-cross-coupling delay lines and orthonormal cross coupling matrices. The simplest  $N$  channel system comprises  $N$  delay lines connecting  $N$  microphone signals to  $N$  loudspeakers, as shown in figure 2. This system generates a single delay at each output for a signal applied to its respective input. The transfer function matrix is

$$X = D = \begin{bmatrix} \exp\{-j\omega T_1\} & 0 & 0 & 0 \\ 0 & \exp\{-j\omega T_2\} & 0 & 0 \\ 0 & 0 & \exp\{-j\omega T_3\} & 0 \\ 0 & 0 & 0 & \dots \\ 0 & 0 & 0 & \exp\{-j\omega T_N\} \end{bmatrix} \quad 5$$

This has a diagonal form since there is no cross coupling. The system is unitary since  $D^H D = I$ .

Figure 3 shows the use of an orthonormal cross coupling matrix in a more complex system of the invention. An orthonormal matrix  $M_1$  is placed before the delay lines

$T_1$ - $T_N$  so that a signal applied to any one input is coupled into every delay line, resulting in a single scaled and delayed reproduction of that signal at every output. The transfer function matrix is

5

$$X = DM_1$$

6

This system is unitary since both  $M_1$  and  $D$  are unitary, and the product of unitary matrices is unitary.

10

Figure 4 shows the use of orthonormal matrices  $M_1$  and  $M_2$  both before and after the delay lines  $T_1$  and  $T_N$ . A single impulse applied to one of the inputs is applied to all  $N$  delay line inputs, and appears at times  $\tau_n$  later at the delay outputs. The  $N$  delayed impulses are then cross coupled to every output. Thus,  $N$  output delays are generated at each output for a single applied impulse. The circuit thus has the property of diffusing the inputs and providing the maximum number of outputs for any input. The matrix transfer function of the circuit is the product of the transfer function matrices of each section

15

$$X = M_2DM_1$$

7

20

Figure 5 shows cascading multiple systems of the form in figure 4. This system generates  $N^2$  scaled delayed reproductions of a signal applied to any single input at every output. Hence the delay density increases rapidly with the number of delay stages.

25

30

The early reflection enhancement system of the invention may also be combined with a non-in-line assisted reverberation system for controlling the global reverberation time so that the reverberation time is similar for all source positions in the room, of the type described in US patent 5,862,233. Such a system comprises multiple microphones positioned to pick up predominantly reverberant sound in a room, multiple loud speakers to broadcast sound into the room, and a reverberation matrix connecting a similar bandwidth signal from each microphone through a reverberator having an impulse response consisting of a number of echoes the density of which increases over time, to a loudspeaker. The reverberation matrix

may connect a similar bandwidth signal from each microphone through one or more reverberators to two or more separate loudspeakers and each of which receives a signal comprising one or more reverberated microphone signal. Figure 6 shows a wideband, N microphone, K loudspeaker non-in-line system. Each of microphones,  $m_1$ ,  $m_2$  and  $m_3$  picks up the reverberant sound in the auditorium. Each microphone signal is split into a number of K of separate paths, and each 'copy' of the microphone signal is transmitted through a reverberator, (the reverberators typically have a similar reverberation time but may have a different reverberation time). Each microphone signal is connected to each of K loudspeakers through the reverberators, with the output of one reverberator from each microphone being connected to each of the amplifiers  $A_1$  to  $A_3$  and to loudspeakers  $L_1$  to  $L_3$  as shown ie one reverberator signal from each microphone is connected to each loudspeaker and each loudspeaker has connected to it the signal from each microphone, through a reverberator. In total there are N.K connections between the microphone and the loudspeakers. While in Figure 6 each microphone signal is split into K separate paths through K reverberators resulting in N.K connections to K amplifiers and loudspeakers, the microphone signals could be split into less than K paths and coupled over less than K reverberators, ie each loudspeaker may have connected to it the signal from at least two microphones each through a reverberator, but be cross-linked with less than the total number of microphones. For example, in the system of Figure 2 the reverberation matrix may split the signal from each of microphones  $m_1$ ,  $m_2$  and  $m_3$  to feed two reverberators instead of three, and the reverberator output from microphone  $m_1$  may then be connected to speakers  $L_1$  and  $L_3$ , from microphone  $m_2$  to speakers  $L_3$  and  $L_2$ , and from microphone  $m_3$  to speakers  $L_2$  and  $L_3$ . It can be shown that the system performance is governed by the minimum of N and K, and so systems of the invention where  $N=K$  are preferred. In Figure 6 each loudspeaker indicated by  $L_1$ ,  $L_2$  and  $L_3$  could in fact consist of a group of two or more loudspeakers positioned around an auditorium. In Figure 6 the signal from the microphones is split prior to the reverberators but the same system can be implemented by passing the supply from each microphone through a single reverberator per microphone and then splitting the reverberated microphone signal to the loudspeakers.

The system simulates placing a secondary room in a feedback loop around the main auditorium with no two way acoustic coupling. The system allows the

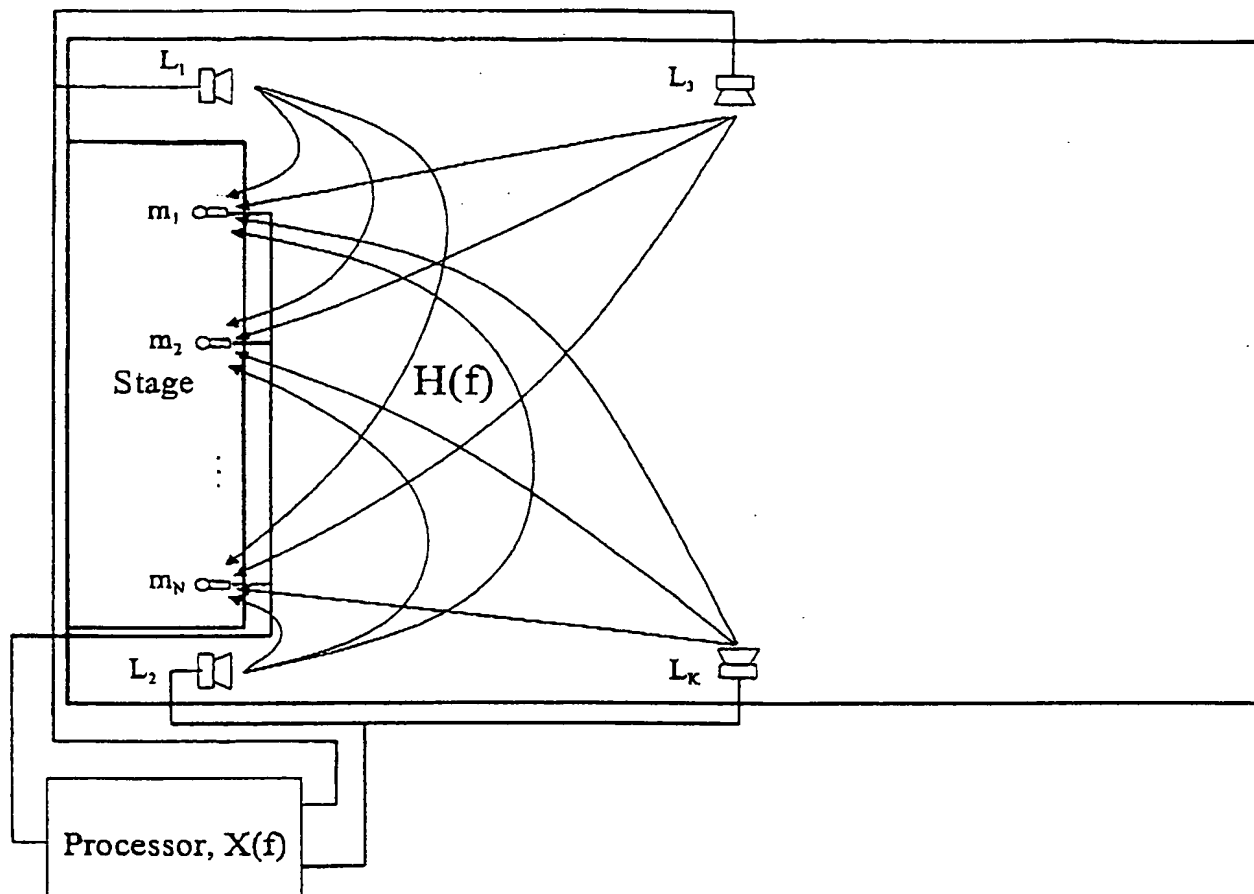
reverberation time in the room to be controlled independently of the steady state density by altering the apparent room volume.

The foregoing describes the invention including preferred forms thereof. Alterations  
5 and modifications as will be obvious to those skilled in the art are intended to be incorporated within the scope hereof.

**CLAIMS**

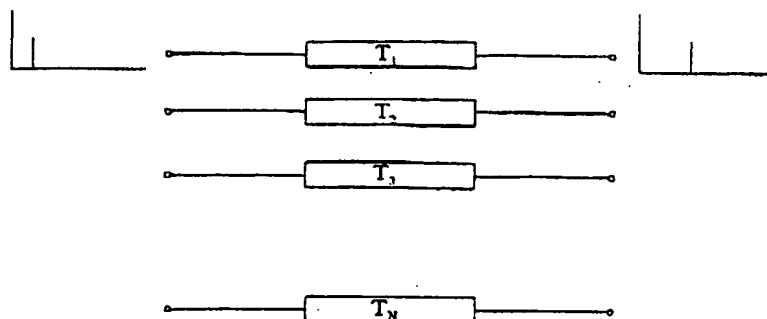
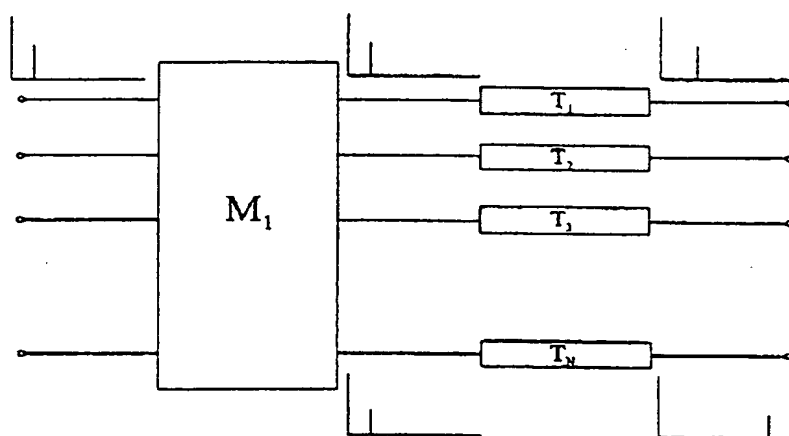
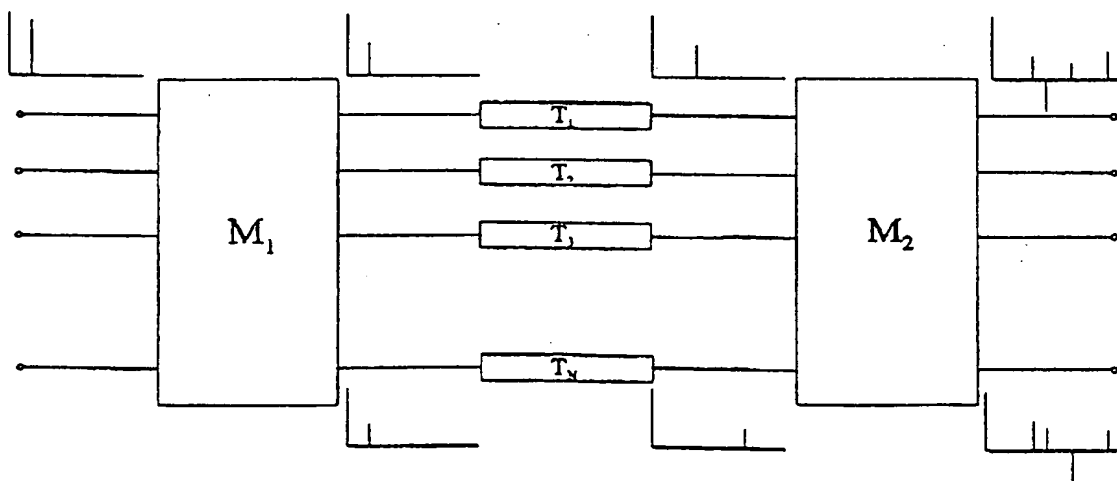
1. An in-line early enhancement generation system comprising:  
one or more microphones positioned close to one or more sound sources so  
as to detect predominantly direct sound;  
an early reflection generation stage which generates a number of delayed  
reproductions of the microphone signals and which has unitary power gain  
whereby the stability of the system is independent of the delay times and  
amplitudes;  
a number of loudspeakers placed to broadcast said early reflected energy  
into the room.
2. An in-line early reflection enhancement system according to claim 1  
wherein the early reflection generation stage also includes at least one cross  
coupling matrix.
3. An in-line early reflection enhancement system according to claim 1  
wherein the early reflection generation stage includes a series connection of  
two or more cross-coupling matrices with a set of delay lines positioned  
between the two matrices.
4. An in-line early reflection generation system according to claim 2 or claim 3  
wherein said cross-coupling matrix or matrices are orthonormal matrices.
5. An in-line early reflection generation system according to claim 1 wherein  
each input is coupled to every output to provide a maximisation of diffusion  
of the input signals to all of the outputs.
6. An in-line early reflection enhancement system according to any one of  
claims 1 to 5 in combination with a wideband non-in-line assisted  
reverberation system which increases apparent room volume, including  
multiple loudspeakers to broadcast sound into the room, and a  
reverberation matrix connecting a similar bandwidth signal from each  
microphone through one or more reverberators having an impulse response  
consisting of a number of echoes the density of which increases over time,  
to one or more loudspeakers.

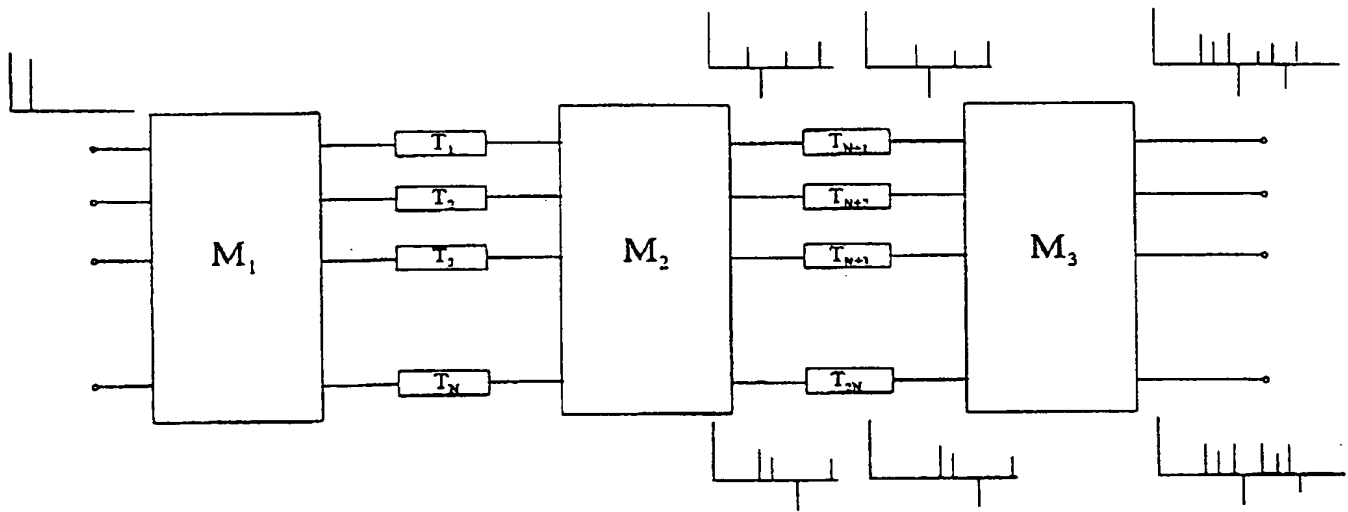
7. An in-line early reflection enhancement system according to claim 6 wherein in said wideband non-in-line assisted reverberation system the reverberation matrix connects a similar bandwidth signal from each microphone through one or more reverberators to at least two loudspeakers each of which receives a signal comprising a sum of at least two reverberated microphone signals.
8. A method for enhancing the acoustics of a room or auditorium comprising detecting predominantly direct sound with one or more microphones positioned close to one or more sound sources, generating a number of delayed reproductions of the microphone signals in an early reflection generation stage and which has unitary power gain whereby the stability of the system is independent of the delay times and amplitudes, and broadcasting said early reflected energy into the room.
9. A method according to claim 8 wherein the early reflection generation stage includes at least one cross coupling matrix.
10. A method according to claim 8 wherein the early reflection generation stage includes a series connection of two or more cross-coupling matrices with a set of delay lines position between the two matrices.
11. A method according to claim 9 or claim 10 wherein said cross-coupling matrix or matrices are orthonormal matrices.
12. A method according to claim 8 wherein each input is coupled to every output to provide a maximisation of diffusion of the input signals to all of the outputs.

**Figure 1**



2 / 4

**Figure 2****Figure 3****Figure 4**

**Figure 5**

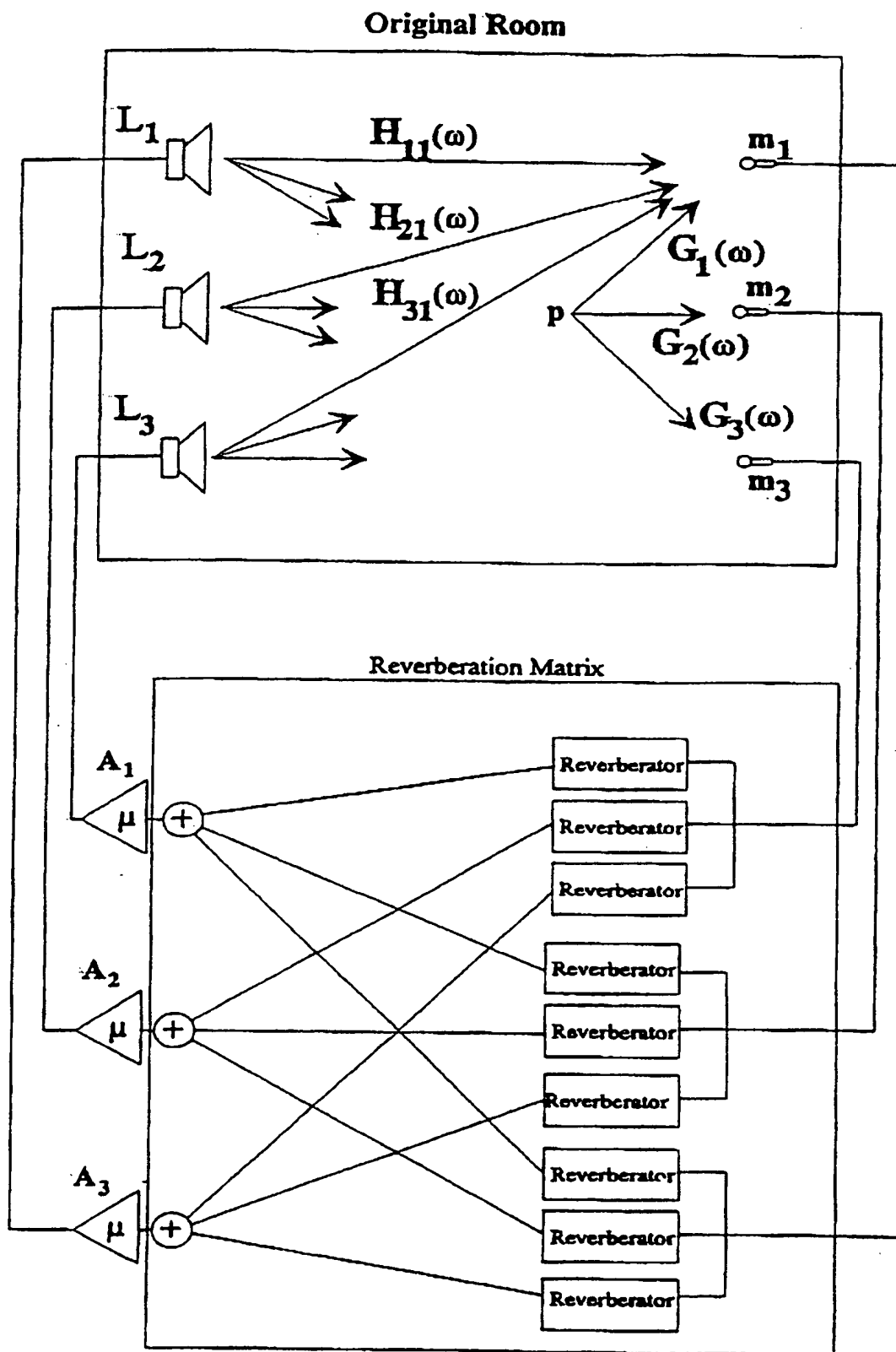


Figure 6

REC'D 27 MARS 2000

WIPO

PCT

Applicant's or agent's file reference 24421 GWW/eaw	<b>FOR FURTHER ACTION</b>	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International application No. PCT/NZ99/00049	International filing date (day/month/year) 23 April 1999	Priority Date (day/month/year) 23 April 1998
International Patent Classification (IPC) or national classification and IPC  Int. Cl. <sup>7</sup> G10K 15/08		
Applicant INDUSTRIAL RESEARCH LIMITED (et al.)		

1.	This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2.	This REPORT consists of a total of 5 sheets, including this cover sheet.  <input type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).  These annexes consist of a total of sheet(s).
3.	This report contains indications relating to the following items:  I <input checked="" type="checkbox"/> Basis of the report II <input type="checkbox"/> Priority III <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability IV <input type="checkbox"/> Lack of unity of invention V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement VI <input checked="" type="checkbox"/> Certain documents cited VII <input type="checkbox"/> Certain defects in the international application VIII <input checked="" type="checkbox"/> Certain observations on the international application

Date of submission of the demand 4 November 1999	Date of completion of the report 10 March 2000
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer  R.W.J. FINZI Telephone No. (02) 6283 2213

**I. Basis of the report**1. With regard to the **elements** of the international application:\*☒ the international application as originally filed.☐ the description,        pages , as originally filed,  
   pages , filed with the demand,  
   pages , received on    with the letter of☐ the claims,        pages , as originally filed,  
   pages , as amended (together with any statement) under Article 19,  
   pages , filed with the demand,☐ the drawings,        pages , as originally filed,  
   pages , filed with the demand,  
   pages , received on    with the letter of☐ the sequence listing part of the description:  
   pages , as originally filed   pages , filed with the demand  
   pages , received on    with the letter of2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).☐ the language of publication of the international application (under Rule 48.3(b)).☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, was on the basis of the sequence listing:☐ contained in the international application in written form.☐ filed together with the international application in computer readable form.☐ furnished subsequently to this Authority in written form.☐ furnished subsequently to this Authority in computer readable form.☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished4. ☐ The amendments have resulted in the cancellation of:☐ the description,        pages☐ the claims,        Nos.☐ the drawings,        sheets/fig.5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).\*\*

\* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

\*\* Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement****1. Statement**

Novelty (N)	Claims 1 - 12	YES
	Claims	NO
Inventive step (IS)	Claims 1 - 12	YES
	Claims	NO
Industrial applicability (IA)	Claims 1 - 12	YES
	Claims	NO

**2. Citations and explanations (Rule 70.7)**

a) EP 827276 A2 (FUJITSU TEN LIMITED) 4 March 1998

b) WO 95/10831 A1 (INDUSTRIAL RESEARCH LIMITED) 20 March 1995

Neither of these citations, taken individually or in obvious combination, disclose the invention as claimed. The claimed invention clearly meets the requirements of Industrial Applicability.

**VI. Certain documents cited****1. Certain published documents (Rule 70.10)**

Application No. Patent No.	Publication date (day/month/year)	Filing date (day/month/year)	Priority date ( valid claim) (day/month/year)
EP 865025	16 September 1998	3 March 1998	3 March 1997

**2. Non-written disclosures (Rule 70.9)**

Kind of non-written disclosure	Date of non-written disclosure (day/month/year)	Date of written disclosure referring to non-written disclosure (day/month/year)
--------------------------------	--	---

**VIII. Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

- 1) Claims 2 to 7 refer to an "early reflection enhancement system". Claim 1, however, is directed to an "early enhancement generation system".
- 2) There are no antecedents in claim 1 for "the delay times" or "the room". A similar objection applies to claim 8.



## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING  
OF A CHANGE(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

WEST-WALKER, Gregory, James  
West-Walker Bennett  
Mobil on the Park  
PO Box 1344  
157 Lambton Quay  
Wellington 6001  
NOUVELLE-ZÉLANDE

Date of mailing (day/month/year) 16 February 2000 (16.02.00)	<b>IMPORTANT NOTIFICATION</b>
Applicant's or agent's file reference 24421 GWW/eaw	
International application No. PCT/NZ99/00049	International filing date (day/month/year) 23 April 1999 (23.04.99)

## 1. The following indications appeared on record concerning:

☐ the applicant    ☐ the inventor    ☒ the agent    ☐ the common representative

## Name and Address

WEST-WALKER, Gregory, James  
Russell McVeagh West-Walker  
Level 18  
Mobil on the Park  
157 Lambton Quay  
Wellington  
New Zealand

## State of Nationality

## State of Residence

## Telephone No.

64 4 499 9058

## Facsimile No.

64 4 499 9306

## Teleprinter No.

## 2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person    ☒ the name    ☒ the address    ☐ the nationality    ☐ the residence

## Name and Address

WEST-WALKER, Gregory, James  
West-Walker Bennett  
Mobil on the Park  
PO Box 1344  
157 Lambton Quay  
Wellington 6001  
New Zealand

## State of Nationality

## State of Residence

## Telephone No.

64 4 499 9058

## Facsimile No.

64 4 499 9306

## Teleprinter No.

## 3. Further observations, if necessary:

## 4. A copy of this notification has been sent to:

<input checked="" type="checkbox"/> the receiving Office	<input type="checkbox"/> the designated Offices concerned
<input type="checkbox"/> the International Searching Authority	<input checked="" type="checkbox"/> the elected Offices concerned
<input checked="" type="checkbox"/> the International Preliminary Examining Authority	<input type="checkbox"/> other:

<b>The International Bureau of WIPO</b> 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer I. Britel Telephone No.: (41-22) 338.83.38
--	---

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NZ 99/00049

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>																						
Int Cl <sup>6</sup> : G10K 15/08																						
According to International Patent Classification (IPC) or to both national classification and IPC																						
<b>B. FIELDS SEARCHED</b>																						
Minimum documentation searched (classification system followed by classification symbols) IPC: G10K 15/IC; H04R 27/IC; H04S																						
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU: IPC as above																						
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPAT: (Reverb: or early (w) reflection#)																						
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>																						
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.																				
P,A	EP 865025 A1 (YAMAHA CORPORATION) 16 September 1998																					
A	EP 827276 A2 (FUJITSU TEN LIMITED) 4 March 1998																					
A	WO 95/10831 A1 (INDUSTRIAL RESEARCH LIMITED) 20 April 1995																					
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex																						
<p>* Special categories of cited documents:</p> <table border="0"> <tr> <td>"A"</td> <td>Document defining the general state of the art which is not considered to be of particular relevance</td> <td>"T"</td> <td>later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>"E"</td> <td>earlier application or patent but published on or after the international filing date</td> <td>"X"</td> <td>document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>"L"</td> <td>document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>"Y"</td> <td>document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>"O"</td> <td>document referring to an oral disclosure, use, exhibition or other means</td> <td>"&amp;"</td> <td>document member of the same patent family</td> </tr> <tr> <td>"P"</td> <td>document published prior to the international filing date but later than the priority date claimed</td> <td></td> <td></td> </tr> </table>			"A"	Document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family	"P"	document published prior to the international filing date but later than the priority date claimed		
"A"	Document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention																			
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone																			
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art																			
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family																			
"P"	document published prior to the international filing date but later than the priority date claimed																					
Date of the actual completion of the international search 20 August 1999		Date of mailing of the international search report 01 SEP 1999																				
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929		Authorized officer  R.W.J. FINZI Telephone No.: (02) 6283 2213																				

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NZ 99/00049

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 93/23847 A1 (INDUSTRIAL RESEARCH LIMITED) 25 November 1993	
A	US 5109419 A (Griesinger) 28 April 1992	

## INTERNATIONAL SEARCH REPORT

### Information on patent family members

**International application No.**  
**PCT/NZ 99/00049**

**This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.**

Patent Document Cited in Search Report				Patent Family Member			
EP	865025	JP	10247089				
EP	827276	EP	509767	JP	5265476	US	5247474
		CA	2065598	JP	4318898	JP	4318899
		JP	4360200	JP	4318785	US	5319468
WO	9510831	AU	80060/94	NZ	274934	US	5729613
WO	9323847	AU	40944/93	EP	641477	NZ	252326
		US	5862233				